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(3) Initials of the Referencer__________

MADRAS RECORD OFFICE

Government of Madras

Public Works DEPARTMENT

G.O. No. 1619-20 (3) Press
~~B.P. No.~~ ~~Mis.~~

Dated 27-6- 1876.

Not to be folded or roughly handled

Proceedings of the Madras Government, Public Works Department,
27th June **1876.** *No.* **1,619.**

Read the following papers:—

No. 559. Endorsement of the Chief Engineer for Irrigation, dated 20th October 1875, No. 1,229.

From R. SMITH, Esq., Officiating Superintending Engineer, Nellore, to Lieutenant-Colonel J. MULLINS, R.E., Chief Engineer for Irrigation and Joint Secretary to Government, Fort St. George, dated Nellore, 19th October 1875, No. 58.

I HAVE the honor to forward the separate notes referred to in paragraph 13 of the joint report on the diversion of the Perryaur submitted by Captain Pennycuick and myself on the 6th instant.

Submitted to Government with reference to G.O., No. 2281, of the 6th August last.

(Signed) J. MULLINS, R.E., Lieut.-Col.,
Chief Engineer for Irrigation.

No. 560. Endorsement of the Chief Engineer for Irrigation, dated Fort St. George, 5th January 1876, No. 14.

Note by Mr. R. Smith.

In the joint report* submitted by Captain Pennycuick and myself on the suggestions recently made for diverting water from the Perryaur for the irrigation of a portion of the Madura District, we promised to record our opinions separately regarding the substitution of a masonry dam for the silt embankment proposed for No. 4 site, and, in stating mine, I must not omit to mention that I was at one time in favor of having a masonry dam, and would have prepared a detailed estimate for one when maturing the scheme if my approximate calculations had not indicated that such a structure would be too costly to recommend, and I have to add that I am still of this opinion.

* Dated 6th October 1875.

2. To construct a masonry dam of the required height successfully it would, I consider, be necessary to arrange for proceeding simultaneously with the masonry throughout the entire length and breadth of the dam and for having the site perfectly dry before commencing building operations. The estimate for the dam must, therefore, include the cost of a temporary escape tunnel of the same water section as that allowed for discharging floods during the construction of the silt embankment proposed by me on the 15th April 1872. This subsidiary, but in my opinion indispensable, work would add considerably to the cost of the dam, and I am inclined to the belief that an outlay of Rupees 19,20,000 would be required to close the valley with a wall of substantial masonry. In this calculation I have assumed that first-class rubble masonry would be used throughout the whole dam, and that the average cost of this masonry would be Rupees 8 per cubic yard.

3. The cost of construction would, no doubt, be reduced by using concrete freely, but whether it would be advisable to do so is extremely doubtful. The

risk attending the use of two distinct kinds of material and the difficulty of preventing leakage between them are questions deserving of consideration in disposing of the proposal.

4. With reference to allowing the discharge of the Perryaur to flow through temporary openings or vents in the dam, I must observe that very superior masonry would be necessary to stand the high velocity that would be generated during freshes in that river, and that the subsequent closing of these outlets with watertight joints would be so tedious and uncertain as to practically condemn the arrangement requiring them.

5. As considerable importance appears to be attached to the closing of the temporary escape, I think it desirable to state that I am convinced it could be securely and easily done without masonry or backing of any kind by dividing the head of the tunnel into bays of convenient size by iron frames, with grooves in them, for iron shutters. The latter would be lowered into their proper places in line in succession, and the closing would not be more difficult than is constantly experienced in working the shutters of some of our existing sluices.

NELLORE,
19th October 1875.

(Signed) R. SMITH,
Offg. Superintending Engineer.

Note by Captain J. Pennycuick, R.E.

I wish to add to the joint report submitted by Mr. Smith and myself a few remarks upon the mode proposed for passing the river under the dam during construction and upon some other matters connected with the project.

2. These remarks refer to points upon which we are not so entirely in agreement as on those referred to in the joint report, though there is not, I think, any great difference of opinion between us, and as I alone am responsible for the proposal, which is the main object of this separate note, we have thought it desirable that it should be made independently of the joint report. Mr. Smith will, however, add his own remarks, from which it will be seen how far we are in agreement.

3. The Chief Engineer, in paragraph 6 of his memorandum, No. 695, of April last, suggests further consideration of "Captain Pennycuick's expedient of raising such dams on a substructure of some sort," and it may be as well to recall the history of the proposals made with reference to this part of the project.

4. Up to my arrival in Madras in April 1870 no doubt had been expressed that a masonry culvert under the dam was the proper means to be used for this purpose; the substitution of a tunnel was first proposed by General Orr with a view of avoiding the difficulty, then supposed to be much greater than I now believe it to be, of constructing a masonry culvert at the Perryaur.

5. I subsequently proposed a culvert of Portland cement concrete as being easier and cheaper to construct than a tunnel, and easier, though not cheaper, than a masonry culvert; this proposal was objected to by Colonel Mullins, his objections being based on arguments which I do not think he would have used had he possessed the information which I had as to what had actually been done with this material,* still less if he could have foreseen what has since been done with it.

* Witness the remark that "it might ormight not do to use a concrete containing only one-ninth of its bulk of cement."

6. I should not, however, now propose the use of this material, not because my belief in its value is in any way diminished, but because I think that the difficulties of executing the necessary work in stone masonry are less than they were formerly supposed to be, and do not outweigh the greater cheapness of the latter material.

7. The cost of the culvert for a dam 205 feet high was estimated by me at Rupees 2,70,000, as against about Rupees 7,00,000 which would be required for a tunnel at the same site, but the real cause of this great difference was not the substitution of a culvert for a tunnel or of Portland cement concrete for masonry (the former, indeed, being more expensive than the latter), but the reduction of waterway obtained by the mode in which I proposed to construct the dam, that is, by completing the flanks to nearly their full height before filling in the central portion. This allowed the valley to be closed to a greater height during the limited time available for this purpose than if the whole width had to be done at once, and so enabled us to use a smaller culvert.

8. I have never understood, and do not now understand, the reasons for which Colonel Mullins objected to this arrangement; in his note, No. 56, of 28th February 1871, he gives no such reasons, but simply says that "it had been decided" that the bund was to be thrown entirely across the river after the completion of the tunnel. I have no recollection of any such decision having been arrived at, and Colonel Mullins' note printed with O.G., No. 2466, of 28th July 1869, in the last part of paragraph 9, distinctly enjoins the course which I afterwards proposed.

Paras. 7 & 8.—The objection to forming the flanks of an earthen bund in a season prior to that in which the central portion would be formed is that the former earthwork would settle independently of the latter and thus render the mass less equally compact and homogeneous. Had an earthen bund formed by manual labor been considered a proper and safe arrangement, the narrowing of the central space by the prior formation of the bund on the flanks would have been unavoidable; but, as by the silting process it became practicable to execute the work much more rapidly, the less safe and satisfactory method was of course abandoned.

9. Not knowing what the objections to this course are, I cannot, of course, answer them, and this is perhaps of the less consequence inasmuch as the reduction of waterway practicable at the lower site is comparatively small. The area of the lake here is so much larger than at No. 3 site that a tunnel (or culvert) of only 1,064 square feet is required even if the whole width of the valley is to be closed at once, and I should not, under any circumstances, care to reduce this below 600 square feet. The cost of the tunnel is estimated by Mr. Smith at Rupees 5,63,000, and a culvert of the same area and running under the whole width of the dam would cost, if of masonry, about Rupees 5,20,000, and, if of Portland cement concrete, about Rupees 7,50,000.

10. By reducing the area of waterway to 600 square feet the cost of the culvert might be reduced to Rupees 3,00,000 for masonry and Rupees 4,20,000 for concrete, and a further reduction of about one-fourth of these sums might be made by reducing the length of the culvert as originally proposed by me, which has also been disallowed by Colonel Mullins for reasons with which I am not acquainted.

Para. 10.—The length of culvert or tunnel depends upon the thickness or width of the bund. The means of passing freshes have to be retained until the bund has been fully completed, and consequently the culvert or tunnel must be of a length not less than the width of the bund section where it may be placed. It was laid down in the instructions contained in Proceedings of the Madras Government, No. 1236, of the 12th May 1870, memorandum, paragraph 7, clause 1, that the tunnel faces were to be six feet clear of the slopes of the bund when of full section.

11. The cost of the tunnel would not be reduced in the same proportion by reducing the waterway, and one of 600 square feet of area would probably cost about Rupees 4,50,000.

12. For my own part I am still strongly in favor of the masonry culvert not so much on grounds of economy as of convenience in construction and of safety, for the tunnel will take longer to construct than the culvert and we have no security against interruption to the work, and danger to the embankment, from fissures in the rock through which it is made.

Para. 12.—Supposing the rock to be of a favorable description, and that at sites Nos. 2 and 3 appeared to be so, the tunnel would be preferable to a culvert, and, with the appliances now available for such work, its construction would be easy and rapid. It would occupy a much shorter time than could have been deemed probable five years ago. Neither during the formation of the bund nor after closure of the tunnel would fissures in the rock through which it had been driven be of any greater or less consequence than they would be were the tunnel left unconstructed. If the fissures be extensive and by their direction dangerous, a bund cannot prudently be abutted on hills composed of such rock.

13. I attach but little importance to the difficulty of closing the tunnel, and this difficulty, if it exists, would apply almost as much to a culvert.* I do not think Colonel Mullins' plan would be effective, as I should question the probability of the silt deposited in water, with no means of draining off the latter, keeping the mouth of the tunnel watertight while the masonry in rear was being built up, but I have long ago matured other arrangements, which, I have little doubt, would be perfectly efficient.

* Not quite as much as the division of the culvert into smaller spans would afford greater facilities for closing.

Para. 13.—The silt to be deposited in front of the upper end of the tunnel would make a closure more water-tight than probably any other possible arrangement. The silt itself would be absolutely impervious to water, and by its close contact with the uneven sides of the cutting leading to the tunnel, it would be the best material possible for preventing the passage of water along those faces. The thickness of silt may be increased to any desired extent within the limits of the length of the open cutting.

Memo. para. 7—5th Proceedings of Madras Government, No. 1236, 12th May 1870.

14. For reasons given in Mr. Smith's and my joint report, and upon which we are entirely agreed, it does not appear that any sub-structure, except a masonry culvert or a tunnel, is practicable save at a disproportionate cost, neither does it appear advisable to attempt to combine the temporary and the permanent escape.

15. I think however—and it is to this point that I specially invite attention—that it is worthwhile to consider whether the dam should not be of masonry instead of earth. I have little doubt that an earthen dam constructed by the silting process would be sound and safe, but it would be folly to deny that there is some element of risk in the matter. The chief danger in my view is that of percolation, not through the dam, but between it and the rock (the puddle trenches inserted in the seat of the dam would not, so far as I can see, be of the smallest use); and, although opinions may differ as to the extent of this danger, it seems unadvisable to incur it if it can be avoided at a reasonable expense.

Para. 15.—A masonry instead of a silted earthen dam is undoubtedly a feasible method of closing the Perryaur. A masonry dam would be as preferable to an earthen bund formed manually as a silted bund is believed to be preferable to a masonry dam. At the same cost silt, as being more water-tight than masonry or concrete, would be the better material, and as regards facility and rapidity of construction silting is decidedly superior. Masonry would have a much better chance of standing were unseasonable freshes of magnitude to occur in the first working season of the bund or dam formation, and with this solitary point in its favor the advantage is believed to end.

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16. This truth is that we have all been somewhat too hasty in rejecting masonry as the material of the dam ; inquiries that I have lately made have convinced me that it should be adopted, and some months ago I wrote demi-officially to Colonel Mullins suggesting that the question should be considered. It is not at all necessary that the whole mass of the dam should be of solid masonry. Concrete divided into cells by means of proper longitudinal and, cross walls may be used to a great extent, and in point of fact, the use of this material is to some extent an actual advantage, as it is lighter than solid masonry, and the risk of crushing, which is the chief one with dams of great height, is diminished.*

* The thickness at bottom necessary to prevent crushing is enormously in excess of that necessary for statical stability; it is, in fact, notorious that no dam of any size has ever been overturned by statical pressure.

Para. 16.—The cellular system of construction is inapplicable as will be more fully explained further on.

17. A dam some seventy feet high has lately been built in America almost entirely of concrete with a mere casing of masonry, the proportion of the latter being apparently less than half what I propose to allow.

Para. 17.—Here the faults of the cellular system are avoided.

18. Fortunately the position of the rock on both sides of the river at No. 4 site has been so accurately determined that an estimate of quantities can be made without difficulty.

19. At the risk of making this report too long, I will describe the section to be given to the dam and three methods of construction which have occurred to me.

20. The former is taken from a formula of Mr. Molesworth's given in one of the late numbers of the Roorkee papers as a modification of Professor Rankine's somewhat complicated one. It is $x = 7{\cdot}5 \sqrt{\frac{h^3}{P}}$ where x is the distance of the rear edge of the dam from the vertical line drawn through the front edge at the top, h the distance from the top, and P a constant depending on the nature of the material, in this case 21,600. Its use is limited by the minima $x = \frac{h}{2}$.

and $x = a + a\frac{h}{10}$ a being the top thickness. In the margin are shown the values of x thus obtained ; the front slope is a simple batter of one in ten. Figure 1 shows the section given by this formula.

	x by formula—	$\frac{h}{2}$	$-\frac{h}{10}$
$h = 0$	0	0	10
10	1·6	5	11
20	4·6	10	12
30	8·4	15	13
40	12·9	20	
50	18·1	25	
60	23·8	30	
70	28·7	35	
80	36·5	40	
90	42·4	45	
100	51·0	50	
110	58 9		
120	67·0		
130	75·8		
140	84·5		
150	93·8		
160	103·3		

Para. 20. It is believed that this formula would give dimensions which would be safe.

21. The face and back of the dam to the extent shown in the sections will be of solid masonry, and longitudinal and cross walls of

Para. 21.—The objection to a combination of walls and concrete is that the settlement of the two materials being unequal spaces must be left,

the same material, six feet thick, will run along the length and breadth of the dam. The longitudinal wall will be forty feet from the face wall, and the cross walls will be eighteen feet apart up to the datum line, above which every other one will be omitted, making them forty-two feet apart, the cells formed by these walls being filled with concrete.

which may prove injurious. Captain Pennycuick's section would, were all the interior masonry walls left out, be unobjectionable so far as essential constructive requirements are concerned. A good many years ago the undersigned designed a dam for the Luckawully reservoir with an arrangement of walls and concrete not materially dissimilar to Captain Pennycuick's design, but the idea was abandoned on reading the opinions of French Engineers on the subject, the certainty of irregular settlements being indisputable.

22. The first method of construction suggested is to allow the water to pass over the dam during construction. At first, of course, the depth passing over would be great, perhaps as much as twenty feet during a great flood, but here the overfall would be small, and as the dam was raised its length would increase rapidly and the depth necessary to pass a given flood would be proportionately diminished.

23. Here we should have the advantage of being able to construct the whole work solidly and homogeneously without having to make connections between old and new work and without having to work in a confined space as must be the case in closing a tunnel or culvert, and it may be considered that this would outweigh the evil of allowing the water to pass over the work during construction; the point is one on which there is considerable room for doubt.

Para. 23.—It would not do to run the risk of damage from allowing freshes to pass over the masonry dam while under construction.

24. If this plan be adopted, the course of procedure would be as follows:—The cross walls, eighteen feet apart and six feet broad, of the portions on the two flanks of the river will first be constructed up to about twenty feet above the river bed as shown in figure 3. Being clear of the ordinary stream, this portion of the work will be constructed with little interruption and no risk.

Paras. 24 to 27.—The remarks in these paragraphs show that Captain Pennycuick has not appreciated the importance of keeping the work as much as possible at one level so that unequal settlements may be reduced to a minimum.

25. Advantage will be taken of the fall of the river, which always takes place in August and September, to encroach upon the bed by means of the temporary dams marked *aa* on figures 4 and 5, and so construct a few more cross walls in the shallower part of the bed; we should, of course, only work from one bank at a time, and it is believed that all the lower part of the dam except a width of about 100 feet at the most might thus be constructed by the end of September of the first season.

26. As soon as the north-east monsoon was over, this gap would be closed by means of similar temporary dams, and the cross walls of the central portion would be constructed; the

work would then consist of a series of piers six feet thick with spaces of eighteen feet between them. It should be mentioned here that these piers are shown on the plan with straight edges, but they would, of course, be joggled where necessary to provide for the bonding in of the longitudinal walls.

27. By means of framed wooden shutters any one or more of these openings might be closed and the longitudinal walls and concrete filling put in to a certain height, the water in the mean time passing through the other openings. The head on the shutters would never be more than seven or eight feet except for a few hours during high floods, and the leakage could be easily disposed of by small pumps so as to allow the masonry to be solidly and carefully constructed. The number of vents to be closed at a time would depend mainly on the state of the stream, and probably five or six feet would be the amount of each successive step in the filling; the cross walls would be kept about fifteen feet above the remainder of the work.

28. Figures 4 and 3 show the plan and elevation of the lower part of the dam and the position of the temporary dams.

29. The masonry face wall is shown three feet thick at the top and nineteen at the bottom. The rear wall is made three feet at the top and fifteen feet at the bottom, and this should be faced with large and well-dressed stones.

30. It is a minor, but by no means insignificant, advantage of this mode of construction that the water rises as the work proceeds, so that some portion will be diverted to the Madura District before the entire completion of the works, and we shall also have the benefit of water-transport for materials during a great part of the time occupied; it so happens that owing to the peculiar conformation of the Kythery Valley, this benefit becomes considerable at a very early period.

30. The sill of the water-shed cutting will be 104 feet above deep bed of river and only 31 feet below full lake level. So the keeping of the water up to the level of the dam would at most enable water, and that in comparatively small quantities, to be diverted to the Madura District one season earlier than would otherwise be practicable. This advantage would be far more than counterbalanced by constant interruptions to the work, which, even supposing that no serious damage were to result, would very possibly postpone the diversion of water for more than one season.

Water-transport would be an advantage resulting from the formation of a lake at once, but it would be necessary several times in a season to re-arrange the jetties or other conveniences for the transfer of materials from carts to boats and *vice versâ*. Indeed, seeing that such materials would generally have to be deposited at some distance from the dam itself, it is doubtful whether water-transport with the necessity for breaking bulk twice and for constructing boats would effect any considerable saving.

31. In case it should be considered undesirable to allow water to go over the work during construction, the method described in the following paragraphs might be adopted, the water being passed under the dam by means of the culverts shown in figures 5 to 8.

32. I have given a considerable area (more than 1,800 square feet) to these culverts, as their cost is insignificant, and it is advisable to take advantage of this fact to reduce the velocity of the water passing through them. The area might with advantage be increased but that there might then be a difficulty in closing them properly within the time available.

33. I should mention here that in my demi-official letter to Colonel Mullins I proposed a somewhat different arrangement to that now recommended for passing water under the dam so as to avoid the necessity of closing the openings under any considerable head, but I had not at that time seen the plans of the lake at No. 4 site, and did not know how large its area is and how slowly the water will rise.

34. The general construction will be the same as described in paragraphs 24 and 25, the vents on the flanks of the stream being first built and the connecting portion of the dam being afterwards put in under cover of temporary dams as described in paragraph 25.

35. There are several ways in which these dams might be constructed; probably the best, as taking up least room, would be to jump two rows of iron rods into the rock, strut these with bamboos and let down outside them a framework of bamboos covered with thatch grass, filling the space between with puddle; the leakage would be slight and might easily be kept down by pumps until the masonry had been got into a sufficient height to enable it to be disregarded. This plan was adopted with great success by Mr. Stevenson under conditions somewhat similar to those with which we have to deal.

36. After this the construction of the dam will go on without interruption; it is possible that a very heavy flood occurring during the second season may pass over the work, but the injury to the latter will be limited to the removal of a few stones.

37. The closing of the culverts should begin immediately after the close of the north-east monsoon, say on the 1st December. Eight out of the eleven openings would be first closed, wooden shutters being put down in front of them, and the leakage through these being kept down by pumps, as it could very easily be, as it is not likely that the water-level would rise to more than twelve or fifteen feet above the sills of the open vents.

38. The vents would be built up with solid masonry to a distance of forty feet, and every care should be taken to make the joints between the closing and the culvert arch as sound and water-tight as possible. Portland cement should be used for this part, and the face of the closing wall and soffit of the projecting portion of the arch should be plastered with Portland cement or asphalte.

This wall could be finished in twenty days at the most, and behind it would be a backing of well-rammed concrete and cross walls at intervals of eighteen feet.

39. In order to allow plenty of time for the closing walls to get well set before any pressure come upon them, the closing of the two last openings should not be begun before the middle of January.

40. It will be seen that these two vents are extended for a length of eighteen feet beyond the face of the dam, and a semi-circular shaft fourteen feet in diameter is built above each of them up to seventy feet from the top of the dam.* The shaft, which will be built as an arch, will resist the pressure of the water surrounding it, and, though it may possibly leak, the leakage will not be more than can be easily kept down by pumps until the face wall is completed.

* Fifty-feet above datum.

41. The closing of these three vents will be managed in the same way as for the others, but a drain will be left underneath them, terminating in a small pipe with a conical mouth, the mouth to be closed by a valve. A long bamboo thrust through the pipe will keep the valve open as long as may be desired. The object of this drain will be explained below.

42. As soon as the closing wall is completed, the space under the shaft will be built up with rough masonry, which should not quite touch the closing wall, but be connected with it by a number of square stones, to transfer the thrust of the water to ten feet above the crown of the arch; the remainder of the shaft will be filled in with concrete to the top.

43. The greatest observed discharge of the Perryaur from the 15th January to the end of February has only been ninety-seven millions* of cubic yards, and the average is about seventy millions* only. As the content of the lake up to the point where the shaft terminates is over 100 millions of cubic yards, there will be ample time to get the filling done before the water rises to the mouth of the shaft.

* Including allowance for the drainage received between No. 1 and No. 4 sites.

44. This process may appear long and complicated in description, but it will not be so in reality. I attach the greatest importance to the accuracy of the connection between the tunnels and the closing walls, and to giving the mouths of the former the form shown, so as to prevent the latter from being thrust away from them by the pressure of the water. It is obvious that, if this form of mouth be adopted, the closing, to ensure good work, must be done from the front, and it is for this purpose that the shafts in front of the three vents to be closed last are provided.

45. Another point to which I attach very great importance is the allowing the masonry of the closing walls to get thoroughly set before any pressure of water is brought upon them. It is for this purpose that the drains mentioned above are provided. There is certain to be some leakage through the filling of the shaft, and, if this were allowed to accumulate in front of the closing wall, the latter would of course be under the full pressure due to the water level outside. By allowing it to run off as fast as it accumulates, the wall can be kept free from pressure until the masonry is thoroughly set, when the valve can be closed by the removal of the bamboo which keeps it open.

46. A third method, which, on the whole, I am disposed to prefer to either of the other two, is to close the mouths of the vents by cast iron shutters, and not to attempt to check any leakage that might take place between the shutters and their bearings, but to allow it to run off freely by drains in the bottom of the vents. By this means no part of the filling of the vents would be subjected to the action of water under pressure at all, and the latter might be left altogether unfilled; but in that case, there would be a somewhat excessive pressure on the piers between the vents, and it is desirable to relieve this as much as possible.

47. Figures 9 to 14 show the arrangements proposed to give effect to this scheme;† the number of vents would be the same as before, but their width at the mouth would be only six feet, as the iron shutters would be unmanageable beyond that breadth; this would reduce the area of the mouths of the vents to about 1,340 square feet (still much more than the area of the tunnel proposed for the earthen dam), but, on the other hand, the width of the openings might be greatly increased after the first few feet, and the velocity of water passing through them consequently diminished; this plan gives the increased area where it is most wanted. The sides of the vents along the narrower part would be faced with well-dressed cut stone, and the shutters would slide on iron bearings carefully fitted into the face of the piers and arches. It would be necessary for these faces to be very carefully dressed, and piers, twelve feet long and fifteen feet high, are run out in front of the main piers to enable any one vent to be temporarily closed in order that the shutter bearings may be got ready. The total cost of this plan is nearly the same as that of the first mentioned, and considerably less than that of the second; the dressed stone facing of the rear wall of the first plan and the masonry shafts and expensive filling to the vents of the second being saved.

† Subject of course to modification in details.

48. It is obvious that the efficiency of this plan depends on the amount of leakage between the shutters and the face of the dam. Provided the drains are made large enough, the loss of water is the only evil caused by this leakage, and, unless this is so great as to cause a serious diminution in the supply available for irrigation, the plan would appear better than either of the others

If the working faces of the shutters and their bearings were carefully planed and well put together, it seems improbable that the leakage could be very great; it would be much less with wooden shutters than with iron ones, and the former would be much cheaper; it is doubtful whether wood could be trusted as regards durability, but when kept constantly wet, well-seasoned wood will often last for very many years. The insertion of a strip of India rubber between the shutter and its bearing would possibily lessen the leakage a good deal; but to be of any use, it must reduce that on each face by one half or more, as there would be two faces to leak instead of one. Figure 15 shows a mode of using India rubber for this purpose. It would probably be impossible to slide the shutters along the India rubber without injury to the latter, but there would be no difficulty at all in moving them into position horizontally. For instance, they might be made of wrought iron in the form of caissons, and floated into position; this would be expensive, but there are many other ways of attaining the same end.

49. With regard to the cost of the works, lime is procurable at Goodaloor, five miles from the foot of the ghaut and fifteen from the site of the dam. I have gone carefully into the details of various means of transport, and have arrived at the conclusion that traction engines will be the best means to employ. Four such engines will be required, and the cost, including plant and all other charges, will not exceed Rupees 2½ per ton, or 2 Annas per parah.* For the pay of bricklayers I allow 1 Rupee per diem, with 25 per cent. added on account of petty establishment, sick men, &c.

* A parah weighs as nearly as possible one hundred weight.

49. The principal material to be brought from a distance for a masonry dam is lime, and of this 400,000 to 410,000 parahs or some 20,000 tons would be required. This is an outside estimate, as the lime would not be slaked before transport.

Supposing the whole of this material to be brought to the work in four seasons of six months each, the average daily traffic would be nearly ... 28 tons

In some further calculations Captain Pennycuick reduces the quantity of lime by one half, so the total load would upon that basis be only 16 tons.

Apparently about 1,000 laborers of sorts would be employed, and their food may be taken to weigh about 2 lbs. per man, say ... ... 1 ,,

Tools and stones would not average ... 1 ,,

Total ... 30 tons

The distance that lime would have to be brought is fifteen miles, and the cost of its transport by carts would be 5 to 5½ Annas a parah (4,000 cubic inches), taking Rupees 30 a month as the hire of a cart. Captain Pennycuick has not given the data for his rate of 2 Annas.

50. The cost of masonry will not exceed the following:—

		RS. A. P.
1 Cubic yard of stone		2 0 0
1½ Bricklayers†		1 14 0
2 Coolies...		1 0 0
2 Parahs Chunnam—		
Cost at kilns	0 6 0	
Carriage to site	0 2 0	
	0 8 0	1 0 0
½ Parah burnt clay		0 2 0‡
4 Parahs sand		0 4 0‡
Sundries		0 12 0
Total per cubic yard ...		7 0 0

† This is much more than our schedules allow for work in the plains.

‡ Fancy prices.

50. The undersigned does not think it safe to estimate the cost of rubble masonry at the Perryaur at Rupees 7 a cubic yard. What is known is that everything there will cost more than twice as much as it does in the plains, and work in the latter which could be accepted would cost more than 3½ Rupees. A great many matters have to be

attended to. The stone used in particular layers all over the dam should approximately be on equal size; there must be no large spaces filled if with chips and mortar after the usual fashion, a fashion not perhaps very objectionable where weights and strains are on a small scale.

51. Colonel Fischer informs me that the *highest rate* paid on the Goodaloor ghaut for masonry was Rupees 6, and a great deal was done at much lower rates; as the only extra expense we have is the carriage of lime, and we have the advantage of concentration and working on a large scale, I think the rate of Rupees 7 allowed is ample; for the arch work over the culvert vents I have allowed Rupees 15, and the same rate for the first twenty-four feet of the closing walls, which must be done with great care, and, as already mentioned, in Portland cement. The same rate has also been allowed for the outer three feet of the rear wall if the water is allowed to pass over the dam during construction. For concrete I have allowed Rupees 4 per cubic yard, which is ample.

51. The front face wall would practically be an independent casing wall, and would have to be built very carefully of coursed rubble. Concrete probably will cost more than Rupees 4 a cubic yard.

Ashlar work, such as would be necessary for a culvert, would cost not less and possibly much more than 40 Rupees a cubic yard.

52. There is a small saddle on the left bank of the river which has to be dammed over, and for this I propose to use an earthen dam, and a very small dam will also be required on the water-shed.

53. The total cost will be by the first plan—

	RS.
15,000 cubic yards masonry at Rupees 15 ...	2,25,000
93,000 ,, ,, at ,, 7 ...	6,51,000
93,000 ,, concrete at ,, 4 ...	3,72,000
Benching rock for foundations	12,000
Shutters	3,000
Working shutters, pumping, &c.	5,000
Temporary dams	8,000
	12,76,000
Dam over saddle on left bank	8,000
,, on water-shed	2,000
Total ...	12,86,000

53. The estimates given in this paragraph would need material modification if they are to be compared with the estimate for a silt dam prepared by Mr. R. Smith, and while it is by no means impossible that the rates allowed might, in practice, be approximated to under unusually good executive arrangements, they will not do as an indication of what this part of the project will probably cost. Cut stone work is everywhere costly when granite is the material used, and for any work of this kind a very ample rate will be necessary.

by the second plan it will be—

	RS.
8,000 cubic yards masonry at Rupees 15	1,20,000
113,000 ,, ,, at ,, 7	7,91,000
3,600 ,, arch work at ,, 15	54,000
85,000 ,, concrete at ,, 4	3,40,000
Benching rock for foundations	27,000
Shutters	4,000
Working shutters, pumping, &c.	2,000
Temporary dams	8,000
	13,46,000
Dam over saddle on left bank	8,000
,, on water-shed	2,000
Total ...	13,56,000

by the third—

	RS.
2,200 cubic yards arch work at Rupees 15	33,000
1,000 ,, masonry at ,, 15	15,000
112,000 ,, ,, at ,, 7	7,84,000
91,000 ,, concrete at ,, 4	3,64,000
Benching rock for foundation	24,000
Shutters 2,200 square feet at Rupees 20	44,000
Working shutters, pumping, &c.	2,000
Temporary dams	8,000
	12,74,000
Dam on saddle on left bank	8,000
,, on water-shed	2,000
Total ...	12,84,000

54. Against this we have to set, as per Mr. Smith's estimates—

	RS.
Escape tunnel	5,63,481
Reservoir embankment	5,22,600
Silting dam and channels	41,500
Tools, plant, and machinery required for earth work	1,50,000
Labor collectors, and travelling batta, 50 per cent. would be saved by the smaller number of men required	38,000
Total ...	13,15,581

All the other items would remain precisely as in Mr. Smith's project, so that it will be seen that the extra cost of a masonry dam over an earthen one is only Rupees 40,000 at the outside.

55. According to the data taken, 190,000 days' work of a bricklayer would be required for the whole work on the first plan, and 210,000 on the second, and to complete it in 900 working days we should want from 210 to 240 per day. I do not, however, think that all the men employed need be skilled masons, but some of them might be ordinary coolies taught to do mason's work. Lieutenant Greer taught numbers of these men to use the jumper, and they did just as well as the regular miners, and I see no reason why they should not be taught to use the trowel as well. With the pay offered we should have no difficulty in getting the number of men we want.

56. In the event of its being determined to take up this project again in earnest, it would be well to bear in mind that the road from the head of the Goodaloor ghaut to the site of the works has not only to be made, but to be traced. The construction will take one season, during which some other preliminary work can be done, and it would be highly desirable that the trace should be made this year, so as to allow the construction to be taken up next July. The country has already been surveyed, and we know almost exactly the line the road must take, so that the actual trace could be made very easily, probably a month or six weeks would do all that is required.

57. It seems very questionable whether any benefit will be obtained from the reference to Engineers in England or elsewhere. The only doubtful point with reference to the earthen dam is its stability ; we know already that no such dam of any thing approaching the height proposed has yet been constructed, and the chances of success at the Perryaur depend solely upon the superiority of earthwork deposited by silting over that executed by the ordinary processes. This point is precisely the one on which English Engineers can give no opinion, for the simple reason that they know nothing about it, having never seen the process in operation on any large scale. With regard to the masonry dam, the question is resolved into one of cost and time ; and these depend upon local considerations.

VELLORE,
13th October 1875.

(Signed) J. PENNYCUICK, Captain, R.E.

SUBMITTED for the information of Government with such marginal remarks on Captain Penycuick's Note* as appear to be required.

* Dated 13th October 1875.

(Signed) A. DEC. SCOTT, Major, R.E.,
Assistant Chief Engineer,
Irrigation Department,
for *Chief Engineer for Irrigation.*

No. 560A. From Colonel J. CROFTON, R.E., Deputy Secretary to the Government of India, Public Works Department, (Civil Works—Irrigation), to Major-General G. W. WALKER, R.E., Secretary to the Government of Madras, Public Works Department, Irrigation Branch, dated Fort William, 28th March 1876, No. 159 I.

I am directed to acknowledge the receipt of your letter, No. 1,194, of 30th April 1875, with which were transmitted the papers connected with the Perryaur project, for the development of irrigation in the Madura District, and which was accompanied by a request that they might be referred through the Secretary of State to the highest engineering authorities in the United Kingdom for consideration and for the elaboration, if possible, of some means whereby the great risks attendant on the proposed method of construction might be eliminated, and, in reply, to make the following observations.

2. The Government of India has attentively considered the papers submitted, and the request of the Madras Government to refer them to engineering authorities in England, and has been awaiting the receipt of the further investigations ordered in paragraph 4 of Madras Government's Resolution, No. 1,193, of 30th April 1875. The result of those investigations has, however, only recently come to hand—*vide* enclosures to Despatch No. 5, of 7th February last, from the Madras Government, to the Secretary of State. Moreover, the Government of India is not yet in possession of the whole of the papers relating to the Perryaur Project, for those last received show that other documents have been reviewed since the 30th April 1875 by the Government of Madras, which have not been forwarded to the Government of India.

Proceedings of the Madras Government, Public Works Department,
27th June 1876. *No.* 1,619.

3. I am to say, however, that the Government of India considers that, if among the Engineers of India whose experience in the construction of irrigation works must far exceed that of those in any other country in the world, a sound opinion cannot be arrived at, it will be hopeless to think of relying on that of any of the English engineering authorities named in the papers sent up by the Government of Madras, as they have had little or no practice in the special branch of engineering with which the scheme under discussion is concerned. The Governor-General in Council, therefore, does not consider that any useful purpose would be served by transmitting the papers connected with this project to the Secretary of State for consideration by English Engineers.

4. The Government of India is, however, willing, so far to meet the views of the Government of Madras, as to refer, when the whole of the papers and information connected with the scheme have been received, the various questions involved for the consideration of a Committee composed of the officers named below:—

Colonel J. Crofton, R.E., Inspector-General of Irrigation Works to the Government of India.

Colonel F. T. Haig, R.E., Chief Engineer of Irrigation to the Bengal Government.

Mr. Bradford Leslie, C.E., Engineer to the Calcutta Municipality.

And in addition, if it seems desirable to the Madras Government, one of its own officers thoroughly acquainted with the locality, and who is also intimate with the details of the project itself.

5. The report on the question of substituting a masonry for an earthen dam, which, it is understood from one of the enclosures to the letter to the Secretary of State above alluded to, was in contemplation some months ago, should also be submitted, together with some further information regarding the Perryaur channel at the site of the proposed dam. In none of the reports is there any clear description of the geological features of the site or of the nature of the rocky stratum, whether fissured or compact throughout. The facilities for obtaining good building stone and lime should also be noticed.

6. The delay, I am to observe, in the disposal of this question will not be of material consequence; as in the present state of the finances, it is not likely that funds will be available for any works except those actually in progress for some time to come.

7. A copy of this communication will be forwarded to the Secretary of State.

No. 561. ORDER THEREON, 27th June 1876, No. 1,619.

IRRIGATION, No. 35.

ORDERED that the following letter be sent:—

(Here enter No. 1,620, dated 27th June 1876).

(A true Extract.)

(Signed) G. W. WALKER, Major-General, R.E.,
Secretary to Government.

To the Chief Engineer for Irrigation.

Exd. A. Grubert.

Spare Copies

PUBLIC WORKS DEPARTMENT,
FORT ST. GEORGE, 27th June 1876.

No. 562.

No. 1,620.

FROM

MAJOR-GENERAL G. W. WALKER, R.E.,
Secretary to the Government of Madras,
Public Works Department,

To

THE SECRETARY TO THE GOVERNMENT OF INDIA,
Public Works Department.

IRRIGATION, No. 35-A.

SIR,—I am directed, in reply to your letter, No. 159, of the 28th March last, to transmit, for the information of the Government of India, a copy of the Proceedings of this Government, as per margin,* containing the further information on the engineering features of the Perryaur project which has been obtained since orders were passed on the papers printed in Proceedings, Madras Government, of the 30th April 1875, No. 1,193.

* No. 2,281, dated 6th August 1875.
,, 205, ,, 26th January 1876.
,, 1,619, ,, 27th June 1876.

2. I am at the same time to transmit a copy of the Proceedings of this Government in the Revenue Department in which the arrangements for ascertaining definitely what results may be expected from the diversion of water from the Perryaur to the plains of Madura will be found detailed.

No. 1,236, dated 16th August 1875.
,, 1,436, ,, 29th September ,,
,, 1,594, ,, 6th November ,,

3. With regard to the latter part of paragraph 5 of your letter, I am to say that Mr. R. Smith, the officer who was best acquainted with the site, No. 4, ultimately chosen for the dam, died in January last, and it is difficult, therefore, to obtain at the moment more precise information as to the nature of the rock at this site. A description of the rock at sites Nos. 2 and 3 is, however, given in paragraph 6 of a Note by the Chief Engineer for Irrigation, and it is believed that the character of the rock there does not materially vary from that at site No. 4. From various parts of Mr. R. Smith's reports it may be inferred that the rock is everywhere solid and compact, *e.g.*, "It is generally admitted that the best foundation for a reservoir embankment is clay, and that the next in order is compact rock. If the Perryaur Lake embankment is constructed at No. 2 or at No. 3 site, the foundation will be the same material, *i.e.*, sound rock." Again "The escape tunnel has been aligned and planned to suit the contour of the solid rock." Also in the memorandum on the head works proposed for No. 4 site: "The reservoir embankment will be composed of silt throughout, and, to guard

Proceedings of the Madras Government, No. 3,763, dated 26th November 1869, copy enclosed.

Paragraph 9 of memorandum, dated 30th October 1871.

Proceedings of the Madras Government, 30th April 1875, No. 1,193.

Paragraph 48, 30th April 1875, No. 1,193.

Dated 15th April 1872, paragraph 3.

against leakage in the base or sides, trenches will be cut in the rock in the bed of the Perryaur and on both banks of this river.

"The tunnel to pass the Perryaur during the formation of the reservoir embankment will be cut in the rock on the left bank of this river."

Paragraph 26.

Referring to the site for the permanent escape, it is remarked that the average level of the compact rock is 120 feet above datum, and there are many other passages tending to show that there is solid rock almost everywhere at no great distance below the surface, while in the bed of the river it is exposed. Though nowhere so recorded, the Chief Engineer for Irrigation, who visited the Perryaur in 1869, is of opinion that the whole of the rock is of igneous formation, and that there is any quantity of stone suitable for either rubble or ashlar masonry. Lime is obtainable at Goodaloor "five miles from the foot of the ghaut and fifteen from the site of the dam."

Paragraph 32.

Paragraph 49 of Captain Pennycuick's Note, dated 13th October 1875.
Proceedings of the Madras Government, No. 1,619, of 27th June 1876.

4. Having now supplied all further information available that can be given regarding this project, I am further directed to say that, with all deference to the judgment of the Government of India, the suggested Committee does not appear to meet the object sought by the Government of Madras. The Governor in Council is of opinion that this scheme should not be considered by a Committee composed only of Indian Engineers. It is not by such a Committee that the object proposed in paragraph 3 of the Proceedings of Government, No. 1,193, of 30th April, can be attained. That object was to obtain the opinion of the highest engineering talent available either in the United Kingdom or elsewhere as to the best means of dealing with the problem that has to be solved—the construction of the proposed work with other materials, such as stone or iron, in lieu of silted earth. There is little or no experience available in this country as to design and construction in such materials; while it is believed that there are extensive works of this nature elsewhere from the constructors and designers of which valuable advice and information might be obtained. If His Excellency the Viceroy in Council is unable to see his way at the present to making the reference suggested, His Grace the Governor in Council will have to consider this important and interesting question as for the present laid aside.

I have the honor to be,

Sir,

Your most obedient servant,

Colonel,

Offg. Under Secy. to Govt., P.W.D.,

for *Secretary to Government.*

Exd. A. Grubert.
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No/2 Endo. heading p 4

17

Note by Mr. R. Smith.

*Dated 6th October 1875.

In the joint Report* submitted by Captain Pennycuick and myself, on the suggestions recently made for diverting water, from the Perryaur, for the irrigation of a portion of the Madura District, we promised to record our opinions separately, regarding the substitution of a masonry Dam for the silt embankment proposed for No. 4 Site, and in stating mine I must not omit to mention that I was, at one time, in favor

of having a masonry Dam, and would
have prepared a detailed Estimate
for one, when maturing the scheme, if
my approximate calculations had
not indicated that such a Structure
would be too costly to recommend,
and I have to add that I am
still of this opinion.

2. To construct a masonry Dam
of the required height, successfully,
it would, I consider, be necessary
to arrange for proceeding simultaneously
with the masonry, throughout the
entire length and breadth of the
Dam, and for having the site

5

perfectly dry before commencing building operations. The Estimate for the Dam must, therefore, include the cost of a temporary Escape tunnel of the same water section as that allowed, for discharging floods during the construction of the Silt Embankment proposed, by me, on the 15th April 1872. This subsidiary but, in my opinion, indispensable work would add considerably to the cost of the Dam, and I am inclined to the belief that an outlay of Rs. 19,20,000 would be required to close the

19

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valley with a wall of substantial masonry. In this calculation I have assumed that first-class rubble masonry would be used throughout the whole Dam, and that the average cost of this masonry would be Rs. 8 per Cubic Yard.

8. The cost of construction would, no doubt, be reduced by using concrete freely, but whether it would be advisable to do so is extremely doubtful. The risk attending the use of two distinct kinds of material, and the difficulty of preventing leakage between them, are questions deserving of consideration

in disposing of the proposal.

4. With reference to allowing the discharge of the Perryaur to flow through temporary openings, or vents, in the Dam, I must observe that, very superior masonry would be necessary to stand the high velocity that would be generated during freshes in that river, and that the subsequent closing of these outlets, with watertight joints, would be so tedious and uncertain as to practically condemn the arrangement requiring them.

5. As considerable importance appears tobe attached to the closing of the Temporary Escape. I think it desirable to State that I am convinced it could be securely and easily done, without masonry or backing of any kind, by dividing the head of the Tunnel into bays of convenient size, by iron frames, with grooves in them for iron Shutters. The latter would be lowered into their proper places, in line, in succession, and the closing would not be more

difficult than is constantly experienced in working the Shutters of some of our existing Sluices.

J. Smith

Offg. Superintending Engineer

Nellore
19th October 1875.

CO 4/2104/75

1. M. 279/2/96

Note by Captain J. Pennycuick R.E.

I wish to add to the joint report submitted by Mr Smith and myself a few remarks upon the mode proposed for passing the river under the dam during construction and upon some other matters connected with the Project.

2. These remarks refer to points upon which we are not so entirely in agreement as on those referred to in the joint report, though there is not, I think, any great difference of opinion between us, and, as I alone am responsible for the

proposal

proposal which is the main object of
this separate note, we have thought it
desirable that it should be
made independently of the joint
report. Mr Smith will however
add his own remarks, from which it
will be seen how far we are in
agreement.

3. The Chief Engineer, in
para 6 of his Memorandum No. 695 of
April last suggests further consi-
deration of "Captain Pennycuick's ex-
pedient of raising such dams on a
substructure of some sort" and it may
be as well to recall the history of
the proposals made with reference
to this part of the project.

+Printed [illegible]

4. Up to my arrival in
Madras in April 1870, no doubt
had been expressed that a
masonry culvert under the dam
was the proper means to be used
for

for this purpose; the substitution of a tunnel was first proposed by General Orr with a view of avoiding the difficulty, then supposed to be much greater, than I now believe it to be, of constructing a masonry culvert at the Periar.

5.

I subsequently proposed a culvert of Portland cement concrete, as being easier and cheaper to construct than a tunnel, and easier, though not cheaper, than a masonry culvert; this proposal was objected to by Colonel Mullins, his objections being based on arguments which I do not think he would have used had he possessed the information which I had as to what had actually been done with this material,* still less if he could have foreseen what

* Witness the remark that "it might or might not do to use a concrete containing only one ninth of it's bulk of cement."

what has since been done with it.

6. I should not however now propose the use of this material, not because my belief in it's value is in any way diminished, but be-cause I think that the difficulties of executing the necessary work in stone masonry are less than they were formerly supposed to be, and do not outweigh the greater cheapness of the latter material.

7. The cost of the culvert for a dam 205 feet high was estimated by me at Rupees 2,70,000, as against about Rupees 700000 which would be required for a tunnel at the same site, but the real cause of this great difference was not the substitution of a culvert for a tunnel, or of Portland cement concrete for masonry (the former

indeed

indeed being more expensive than the latter) but the reduction of waterway obtained by the mode in which I proposed to construct the dam, that is, by completing the flanks to nearly their full height before filling in the central portion. This allowed the valley to be closed to a greater height during the limited time available for this purpose, than if the whole width had to be done at once, and so enabled us to use a smaller culvert

8. I have never understood and do not now understand the reasons for which Colonel Mullins objected to this arrangement; in his note No. 56 of 28th February 1871 he gives no such reasons but simply says that "it had been decided" that the bund was to be thrown entirely across the river after the completion of the tunnel. I have no recollection of any such decision having been arrived at; and Colonel

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Colonel Mullins's note printed with O. G. No. 2466 of 28th July 1869, in the last part of para 9, distinctly enjoins the course which I after-wards proposed.

9. Not knowing what the objections to this course are; I cannot of course answer them; and this is perhaps of the less conse-quence inasmuch as the reduction of waterway practicable at the lower site, is comparatively small. The area of the lake here is so much larger than at No. 3 site that a tunnel (or culvert) of only 1064 square feet is required, even if the whole width of the valley is to be closed at once and I should not under any circumstances care to reduce this below 600 square feet. The cost of the tunnel is estimated by Mr. Smith at Rupees 5,63,000 and a

culvert

culvert of the same area, and running under the whole width of the dam would cost, if of masonry, about Rupees 5,20,000, and if of Portland cement concrete about Rs 7,50,000.

10. By reducing the area of waterway to 600 square feet the cost of the culvert might be reduced to Rupees 3,00,000 for masonry and Rs 4,20,000 for concrete; and a further reduction of about $\frac{1}{4}$ of these sums might be made by reducing the length of the culvert as originally proposed by me, which has also been disallowed by Colonel Mullins for reasons with which I am not acquainted.

The length depends upon the width of base of bund

11. The cost of the tunnel would not be reduced in the same proportion by reducing the waterway and one of 600 square feet of area would probably cost about Rupees 4,50,000.

12. For my own part, I am still

still strongly in favour of the masonry culvert, not so much on grounds of economy as of convenience in construc-tion, and of safety; for the tunnel will take longer to construct than the cul-vert, and we have no security against interruption to the work, and danger to the embankment, from fissures in the rock through which it is made.

13. I attach but little importance to the difficulty of closing the tunnel, and this difficulty if it exists, would apply almost as much to a culvert.* I do not think Colonel Mullin's plan would be effective, as I should question the probability of the silt, deposited in water, with no means of draining off the latter, keeping the mouth of the tunnel watertight while the masonry in rear was being

* Not quite as much as the division of the culvert into smaller spans would afford greater facilities for closing.

We can [illegible] only [illegible] differ[illegible] rock af[illegible] than [illegible] danger wh[illegible] while ope[illegible] [illegible] closed -

I differ [illegible] from C[illegible] [illegible] views [illegible] I am [illegible] that silt [illegible] under the c[illegible] intended [illegible] be perfectly [illegible] its density [illegible] different to [illegible] [illegible]

being built up, but I have long ago matured other arrangements, which I have little doubt would be perfectly efficient.

14. For reasons given in Mr. Smith's and my joint report, and upon which we are entirely agreed, it does not appear that any sub-structure except a masonry culvert or a tunnel, is practicable save at a disproportionate cost, neither does it appear advisable to attempt to combine the temporary and the permanent escape.

15. I think however, and it is to this point that I specially invite attention, that it is worth while to consider whether the dam should not be of masonry instead of earth. I have little doubt that an earthen dam constructed by the silting process would be sound and safe, but it would be folly to deny that there is some

element

There is some risk
in the carrying out
of every Engineering [illegible]

element of risk in the matter. The chief danger, in my view, is that of percolation, not through the dam, but between it and the rock (the puddle trenches inserted in the seat of the dam would not, so far as I can see, be of the smallest use) and although opinions may differ as to the extent of this danger, it seems unadvisable to incur it if it can be avoided at a reasonable expense.

6. The truth is that we have all been somewhat too hasty in rejecting masonry as the material of the dam; enquiries that I have lately made have convinced me that it should be adopted, and some months ago, I wrote demi officially to Colonel Mullins suggesting that the question should be considered. It is not at all necessary that the whole mass of the dam should be of solid

masonry.

*The thickness at bottom necessary to prevent crushing is enormously in excess of that necessary for statical stability; it is in fact notorious that no dam of any size has ever been overturned by statical pressure.

masonry. Concrete, divided into cells by means of proper longitudinal and cross walls may be used to a great extent, and in point of fact, the uses of this material is to some extent an actual advantage, as it is lighter than solid masonry, and the risk of crushing which is the chief one with dams of great height, is diminished.*

17. A dam some 70 feet high has lately been built in America, almost entirely of concrete with a mere casing of masonry, the proportion of the latter being apparently less than half what I propose to allow.

18. Fortunately the position of

of the rock on both sides of the river at No. 4 site had been so accurately determined that an estimate of quantities can be made without difficulty.

19. At the risk of making this report too long, I will describe the section to be given to the dam and three methods of construction which have occurred to me.

20. The former is taken from a formula of Mr Molesworth's given in one of the late numbers of the Roorkee papers, as a modification of Professor Rankine's somewhat complicated one. It is $x = 7.5\sqrt{\frac{h^3}{P}}$ where x is the distance of the rear edge of the dam

	x by formula	$\frac{h}{2}$	$x + \frac{h}{10}$
h = 0	0	0	10
10	1.6	5	11
20	4.6	10	12
30	8.4	15	13
40	12.9	20	
50	18.1	25	
60	23.8	30	
70	28.7	35	
80	36.5	40	
90	42.4	45	
100	51.0	50	
110	58.9		
120	67.0		
130	75.8		
140	84.5		
150	93.8		
160	103.3		

dam from the vertical line drawn through the front edge at the top, h the distance from the top, and P a constant depending on the nature of the material, in this case 21,600. Its use is limited by the

minima $x = \frac{h}{2}$

and $x = a + \frac{h}{10}$, a being the top thickness. In the margin are shown the values of x thus obtained; the front slope is a simple batter of one in ten. Figure 1 shows the section given by this formula.

21. The face and back of the dam to the extent shown in the sections will be of solid masonry, and longitudinal and cross walls of the same material, six feet thick, will run along the length and breadth of the dam. The longitudinal wall will be 40 feet from the face wall, and the cross walls will be 18 feet apart up to the datum line, above which every other one will be omitted making them 42 feet apart; the cells formed by these walls being filled with concrete

The objection to a Combination of walls & concrete is that the settlements being unequal the [illegible] the lift

concrete.

22. The first method of construction suggested is to allow the water to pass over the dam during construction. At first of course the depth passing over would be great, perhaps as much as 20 feet during a great flood, but here the over fall would be small, and as the dam was raised its length would increase rapidly and the depth necessary to pass a given flood would be proportionately diminished.

23. Here we should have the advantage of being able to construct the whole work solidly and homogeneously, without having to make connections between old and new work, and without having to work in a confined space, as must be the case in closing a tunnel or culvert, and it may be considered that this would outweigh the evil of allowing the water to pass over the work during construction; the point is one on which

there

which ... injurious ... masonry wa... out, so far as ... reservoir wit... arrangemen... resembling ... design but th... was founded ... the opinions of ... Engineers an... the certainty ... settlements ... indisputabl...

there is considerable room for doubt. 15 39

24. If this plan be adopted the course of procedure would be as follows. The cross walls, eighteen feet apart, and six feet broad, of the portions on the two flanks of the river will first be constructed up to about 20 feet above the river bed, as shown in fig. 3. Being clear of the ordinary stream this portion of the work will be constructed with little interruption and no risk.

25. Advantage will be taken of the fall of the river, which always takes place in August and September, to encroach upon the bed by means of the temporary dams marked a, a, on figures 4 and 5, and so construct a few more cross walls in the shallower part of the bed; we should of course only work from one bank at a time, and it is believed that all the lower part of the dam except a width of about 100 feet at the most, might thus be constructed

by

by the end of September of the first season:

26. As soon as the North East Monsoon was over, this gap would be closed by means of similar temporary dams, and the cross walls of the central portion would be constructed; the work would then consist of a series of piers six feet thick with spaces of eighteen feet between them. It should be mentioned here that these piers are shown on the plan with straight edges, but they would of course be joggled where necessary to provide for the bonding in of the longitudinal walls.

7. By means of framed wooden shutters any one or more of these openings might be closed and the longitudinal walls and concrete filling put in to a certain height, the water in the mean time passing

through

through the other openings. The head on the shutters would never be more than seven or eight feet, except for a few hours during high floods, and the leakage could be easily disposed of by small pumps, so as to allow the masonry to be solidly and carefully constructed. The number of vents to be closed at a time would depend mainly on the state of the stream, and probably five or six feet would be the amount of each successive step in the filling; the cross walls would be kept about fifteen feet above the remainder of the work.

28. Figures 4 and 3 show the plan and elevation of the lower part of the dam and the position of the temporary dams.

29. The masonry face wall is shown 3 feet thick at the top and 19 at the bottom. The rear wall is made 3 feet

at

at the top and fifteen feet at the bottom, and this should be faced with large and well dressed stones.

30. It is a minor, but by no means insignificant advantage of this mode of construction that the waters rises as the work proceeds, so that some portion will be diverted to the Madura District before the entire completion of the works, and we shall also have the benefit of water transport for materials during a great part of the time occupied; it so happens that owing to the peculiar conformation of the Vyghery valley, this benefit becomes considerable at a very early period.

I think the advantage is almost entirely imaginary. The sill of cutting will be 104 feet above [illegible] 31 feet below [illegible] lake level so only one season at most could be saved.

I doubt if water transport would be an advantage

1. In case it should be considered undesirable to allow water to go over the work during construction, the method described in the following

following paragraphs might be adopted, the water being passed under the dam by means of the culverts shown in figures 5 to 8.

32. I have given a considerable area, (more than 1800 square feet) to these culverts, as their cost is insignificant, and it is advisable to take advantage of this fact to reduce the velocity of the waters passing through them. The area might with advantage be increased, but that there might then be a difficulty in closing them properly within the time available.

33. I should mention here that in my demi Official letter to Colonel Mullins I proposed a somewhat different arrangement to that now recommended for passing waters under the dam, so as to avoid the

the necessity of closing the openings under any considerable head, but I had not at that time seen the plans of the lake at No. 4 site, and did not know how large its area is, and how slowly the water will rise.

34. The general construction will be the same as described in paras 24 and 25, the vents on the flanks of the stream being first built and the connecting portion of the dam being afterwards put in under cover of temporary dams as described in para 25.

35. There are several ways in which these dams might be constructed; probably the best, as taking up least room, would be to jump two rows of iron rods into the rock, strut

these

these with bamboos and let down out-side them a framework of bamboos covered with thatch grass, filling the space between with puddle; the leakage would be slight and might easily be kept down by pumps until the masonry had been got in to a sufficient height to enable it to be disregarded. This plan was adopted with great success by Mr Stevenson under conditions somewhat similar to those with which we have to deal.

36. After this the construction of the dam will go on without interruption; it is possible that a very heavy flood occurring during the second season may pass over the work, but the injury to the latter will be limited to the removal of a few stones.

37. The closing of the culverts should begin immediately after the close of the North East Monsoon; say

say on the 1st December. Eight out of the eleven openings would be first closed; wooden shutters being put down in front of them, and the leakage through these being kept down by pumps, as it could very easily be, as it is not likely that the water level would rise to more than twelve or fifteen feet above the sills of the open vents.

38. The vents would be built up with solid masonry to a distance of forty feet, and every care should be taken to make the joints between the closing and the culvert arch as sound and water tight as possible. Portland cement should be used for this part, and the face of the closing wall and soffit of the projecting portion of the arch should be plastered with Portland cement or asphalte.

This

This wall could be finished in twenty days at the most, and behind it would be a backing of well rammed concrete, and crofs walls at intervals of eighteen feet.

39. In order to allow plenty of time for the closing walls to get well set before any prefsure come upon them, the closing of the two last openings should not be begun before the middle of January

40. It will be seen that these two vents are extended for a length of 18 feet beyond the face of the dam, and a semi circular shaft 14 feet in diameter is built above each of

* 50 feet above datum them up to 70 feet from the top of the dam*

The shaft, which will be built as an arch, will resist the prefsure of the water surrounding it, and though it may pofsibly leak, the leakage will not be more than can be easily kept down by pumps until the face wall

it

is completed.

41. The closing of these three vents will be managed in the same way as for the others, but a drain will be left underneath them terminating in a small pipe with a conical mouth; the mouth to be closed by a valve. A long bamboo thrust through the pipe will keep the valve open as long as may be desired. The object of this drain will be explained below.

42. As soon as the closing wall is completed, the space under the shaft will be built up with rough masonry, which should not quite touch the closing wall, but be connected with it by a number of square stones, to transfer the thrust of the water, to ten feet above the crown of the arch; the remainder of the shaft will be filled in with concrete to the top.

43. The greatest observed

discharge

discharge of the Periar from the 15th January to the end of February has only been 97* millions of cubic yards and the average is about 70* millions only. As the content of the lake up to the point where the shaft terminates is over 100 millions of cubic yards there will be ample time to get the filling done before the water rises to the mouth of the shaft.

* Including allowance for the drainage received between No 1 and No 4 sites —

44. This process may appear long and complicated in description, but it will not be so in reality. I attach the greatest importance to the accuracy of the connection between the tunnels and the closing walls, and to giving the mouths of the former the form shown, so as to prevent the latter from being thrust away from them by the pressure of the water. It is obvious that if this form of mouth be adopted the closing, to ensure good work

work must be done from the front, and it is for this purpose that the shafts in front of the three vents to be closed last are provided.

45. Another point to which I attach very great importance is the allowing the masonry of the closing walls to get thoroughly set before any pressure of water is brought upon them. It is for this purpose that the drains mentioned above are provided. There is certain to be some leakage through the filling of the shaft and if this were allowed to accumulate in front of the closing wall, the latter would of course be under the full pressure due to the water level outside. By allowing it to run off as fast as it accumulates, the wall can be kept free from pressure until the masonry is thoroughly set, when the valve can be closed

by

by the removal of the bamboo which keeps it open.

46. A third method, which on the whole I am disposed to prefer to either of the other two, is to close the mouths of the vents by cast iron shutters, and not to attempt to check any leakage that might take place between the shutters and their bearings, but to allow it to run off freely by drains in the bottom of the vents. By this means no part of the filling of the vents would be subjected to the action of water under pressure at all, and the latter might be left altogether unfilled, but in that case there would be a somewhat excessive pressure on the piers between the vents, and it is desirable to relieve this as much as possible.

47. Figs 9 to 14 show the arrangements proposed

proposed to give effect to this scheme;* the number of vents would be the same as before, but their width at the mouth would be only 6', as the iron shutters would be unmanageable beyond that breadth; this would reduce the area of the mouths of the vents to about 1340 square feet (still much more than the area of the tunnel proposed for the earthen dam) but on the other hand the width of the openings might be greatly increased after the first few feet, and the velocity of water passing through them consequently diminished; this plan gives the increased area where it is most wanted. The sides of the vents along the narrower part would be faced with well dressed cut stone, and the shutters would slide on iron bearings carefully fitted into the face of the piers and arches.

** subject of course to modification in details —*

It

It would be necessary for these faces to be very carefully dressed, and piers twelve feet long and fifteen feet high are run out in front of the main piers, to enable any one vent to be temporarily closed in order that the shutter bearings may be got ready. The total cost of this plan is nearly the same as that of the first mentioned, and considerably less than that of the second; the dressed stone facing of the rear wall of the first plan, and the masonry shafts and expensive filling to the vents of the second being saved.

48. It is obvious that the efficiency of this plan depends on the amount of leakage between the shutters and the face of the dam. Provided the drains are made large enough the loss of water is the only evil

evil caused by this leakage, and unless this is so great as to cause a serious diminu-tion in the supply available for irriga-tion, the plan would appear better than either of the others. If the working faces of the shutters and their bearings were carefully planed and well put together, it seems improbable that the leakage could be very great; it would be much less with wooden shutters than with iron ones, and the former would be much cheaper; it is doubtful whether wood could be trusted as regards durability, but when kept constantly wet well seasoned wood will often last for very many years. The insertion of a strip of India rubber between the shutter and its bearing would possibly lessen the leakage a good deal, but to be of any use it must reduce that on each face by one half or more, as there would be

two

two faces to leak instead of one. Fig: 15 shows a mode of using India rubber for this purpose. It would probably be impossible to slide the shutters along the India rubber without injury to the latter, but there would be no difficulty at all in moving them into position horizontally. For instance they might be made of wrought iron in the form of caissons, and floated into position; this would be expensive, but there are many other ways of attaining the same end.

The shutters would not slide on india rubber under pressure.

49. With regard to the cost of the works; lime is procurable at Goodaloor, five miles from the foot of the ghât and fifteen from the site of the dam. I have gone carefully into the details of various means of transport, and have arrived at the conclusion that traction engines will be the best means to employ. Four such engines will be required, and

Does this mean from the quarries to the dam

and the cost, including plant and all other charges, will not exceed Rupees 2½ per ton, or 2 annas per para.*

* A para weighs as nearly as possible one hundred weight.

2⅓ annas a ton a mile & with no return load the distance is double [illegible] 1⅓ annas a ton a mile which [illegible]

For the pay of bricklayers I allow one rupee per diem, with 25 percent added on account of petty establishment, sick men &ca

50. The cost of masonry will not exceed the following.

	Rs. A. P.
1 Cubic yard of stone	2 - " - "
1½ Bricklayers*	1 - 14 - "
2 Coolies	1 - " - "
2 Paras Chunam	
Cost at kilns " - 6 - "	
Carriage to site " - 2 - "	
" - 8 - "	1 - " - "
1/2 Para burnt clay	" - 2 - " +
4 — do. Sand	" - 4 - " +
Sundries	" - 12 - "
Total per Cubic yard	7 - " - "

* This is much more than our schedules allow for work in the plains

No allowance for distance over which materials will have to be carried.

\+ Fancy prices -

Possibly 8 Rupees would be a sufficient rate

51. Colonel Fischer informs me that the highest rate paid on the Goodaloor ghât for masonry was Rupees 6, and a great deal was done at much lower rates; as the only extra expense we have is the carriage of lime, and we have the advantage of concen-tration and working on a large scale, I think the rate of Rupees 7 allowed is ample; for the arch work over the cul-vert vents I have allowed Rupees 15, and the same rate for the first 24 feet of the closing walls, which must be done with great care and, as already mentioned, in Portland cement. The same rate has also been allowed for the outer three feet of the rear wall if the water is allowed to pass over the dam during construction. For concrete I have allowed Rupees 4 per cubic yard, which is ample.

Question
5 or 6 Rupees probably.

52. There is a small saddle

on

on the left bank of the river which has to be dammed over, and for this I propose to use an earthen dam, and a very small dam will also be required on the water shed.

53. The total cost will be by the first plan,

	Rs.
15,000 Cubic yards Masonry at Rs 15	2,25,000
93,000 — " — D° — at — 7	6,51,000
93,000 — " — Concrete at — 4	3,72,000
Benching rock for foundations	12,000
Shutters	3,000
Working shutters, pumping &ca.	5,000
Temporary dams	8,000
	12,76,000
Dam over saddle on left bank	8,000
— D° — on Watershed	2,000
Total Rs	12,86,000

by

by the second plan it will be,

		Rs
8,000	Cubic yards Masonry at Rs 15	1,20,000
113,000	Do at 7	7,91,000
3,600	Arch work at 15	54,000
85,000	Concrete at 4	3,40,000
	Benching rock for foundations	27,000
	Shutters	4,000
	Working shutters, pumping &ca.	2,000
	Temporary dams	8,000
		13,46,000
	Dam over saddle on left bank	8,000
	Do on watershed	2,000
	Total Rs	13,56,000

by the third

		Rs
2,200	Cubic yards Arch work at Rs 15	33,000
1,000	Masonry at 15	15,000
112,000	Do at 7	7,84,000
91,000	Concrete at 4	3,64,000
	Benching rock for foundation	24,000
	Shutters 2200 Sqre. ft. at Rs 20	44,000
	Working shutters, pumping &ca.	2,000
	Temporary dams	8,000
		12,74,000
	Dam on saddle on left bank	8,000
	Do on watershed	2,000
	Total Rs	12,84,000

[Pencil notes in left margin:]
200000
113000
90000
85000
206600
Sundries 92200
1936200
with Cement [illegible]
11600 x 40 = 464,000
198000 x 5 = 990,000
other works 57000
Sundries 75000
1580000

54. Against this we have to set, as per Mr Smith's estimates.

Escape tunnel	5,63,481
Reservoir embankment	5,22,600
Silting dam and channels	41,500
Tools, plant and machinery required for earth work	1,50,000
Labour, collectors, and travelling batta, 50 per cent would be saved, by the smaller number of men required	38,000
Total Rs	13,15,581

10 Rupees a C[illegible] [illegible] Tunnelling & is a very high[illegible]

All the other items would remain precisely as in Mr Smith's project, so that it will be seen that the extra cost of a masonry dam over an earthen one is only Rupees 4,000 at the outside.

55. According to the data taken, 90,000 day's work of a bricklayer would be required for the whole work on the first plan, and 210,000 on the second, and

61/26

and to complete it in 900 working days we should want from 210 to 240 per day. I do not however think that all the men employed need be skilled masons, but some of them might be ordinary coolies taught to do mason's work; Lieutenant Greer taught numbers of these men to use the jumper, and they did just as well as the regular miners, and I see no reason why they should not be taught to use the trowel as well. With the pay offered we should have no difficulty in getting the number of men we want.

56. In the event of its being determined to take up this Project again in earnest, it would be well to bear in mind that the road from the head of the Goodaloor ghat to the site of

of the works has not only to be made, but to be traced. The construction will take one season during which some other preliminary work can be done, and it would be highly desirable that the trace should be made this year, so as to allow the construction to be taken up next July. The country has already been surveyed and we know almost exactly the line the road must take, so that the actual trace could be made very easily; probably a month or six weeks would do all that is required.

7. It seems very questionable whether any benefit will be obtained from the reference to Engineers in England or elsewhere. The only doubtful point with reference to the earthen dam

63 27

dam is its stability; we know already that no such dam of any thing approaching the height proposed has yet been constructed, and the chances of success at the Periar depend solely upon the superiority of earthwork deposited by silting over that executed by the ordinary processes. This point is precisely the one on which English Engineers can give no opinion, for the simple reason that they know nothing about it, having never seen the process in operation on any large scale.

With regard to the masonry dam, the question is resolved into one of cost and time; and these depend upon local

consideration

Cls 1/2104/75

considerations.

John Pennycuick
Capt. R.E.

Vellore
13rd October 1875

P.W. 279/1/96.

No. 559

The following remarks are intended to be printed in half margin against the paras to which they refer.

p 28.
65

No. 14

Inclosures 6

Submitted for the information of Government with such marginal remarks on Captain Pennycuick's + note as appear to be required.

+ dated 13th Octr /75.

(Sd.) A. W. Scott
Major R.E.

Fort Saint George
5th January 1876

Asst. Chief Engineer
Irrigation Department

In Chief Engineer for Irrigation

double col: 8 p 29

Paras 7 & 8.

The objection to forming the flanks of an earthen bund in a season prior to that in which the central portion would be formed is that the former earthwork would settle independently of the latter and thus render the mass less equally compact and homogeneous. Had an earthen bund formed by manual labour been considered a proper and safe arrangement, the narrowing of the central space by the prior formation of the bund on the flanks would have

have been unavoidable, but as by
the silting process it became practicable
to execute the work much more rapidly,
the less safe and satisfactory method
was of course abandoned.

The length of culvert or tunnel Para 10
depends upon the thickness or width
of the bund. The means of passing
freshes have to be retained until the
bund has been fully completed and
consequently the culvert or tunnel must
be of a length not less than the width
of the bund section where it may be
placed. It was laid down in the
instructions contained in Proceedings
of the Madras Government No 1236
of the 12th May 1870 memo para 7
clause 1 that the tunnel faces were to be
feet clear of the slopes of the bund
when of full section.

Supposing the rock to be of a favorable Para 12
description, and that at sites No 2 and
appeared to be so, the tunnel would
be preferable to a culvert, and with the
appliances now available for such work
construction would be easy and rapid.

It

67 30

It would occupy a much shorter time than ~~it~~ could have been deemed probable 5 years ago. Neither during the formation of the bund nor after closure of the tunnel would fissures in the rock through which it had been driven be of any greater or less consequence than they would be were the tunnel left unconstructed. If the fissures be extensive and by their direction dangerous a bund cannot prudently be abutted on hills composed of such rock

Para 13

Memo para 7 - 5th P.W. G.N. 1236 - 12th May/70

The silt to be deposited in front of the upper end of the tunnel would make a closure more water tight than probably any other possible arrangement. The silt itself would be absolutely impervious to water and by its close contact with the uneven sides of the cutting leading to the tunnel it would be the best material possible for preventing the passage of water along those faces. The thickness of silt may be increased to any desired extent within the limits of the length of the open cutting

A

A masonry instead of a silted earthen dam is undoubtedly a feasible method of closing the Perryaur - A masonry dam would be as preferable to an earthen bund formed manually, as a silted bund is believed to be preferable to a masonry dam. At the same cost silt, as being more watertight than masonry or concrete, would be the better material, and as regards facility and rapidity of construction silting is decidedly superior. Masonry would leave a much better chance of standing were unseasonable freshes of magnitude to occur in the first working season of the bund or dam formation and with this solitary point in its favor the advantage is believed to end. Para 15.

The cellular system of construction is inapplicable, as will be more fully explained further on. Para 16

Here the faults of the cellular system are avoided. Para 17

It is believed that this formula would give dimensions which would be safe — Para 20

The

Para 21 The objection to a combination of walls and concrete is that the settlement of the two materials being unequal spaces must be left which may prove injurious. Captain Pennycuick's section would, were all the interior masonry walls left out, be unobjectionable so far as essential constructive requirements are concerned. A good many years ago the undersigned designed a dam for the Luckawully reservoir with an arrangement of walls and concrete not materially dissimilar to Captain Pennycuick's design, but the idea was abandoned on reading the opinions of French Engineers on the subject the certainty of irregular settlements being indisputable.

Para 23. It would not do to run the risk of damage from allowing freshes to pass over the masonry dam while under construction.

Paras 24 to 27. The remarks in these paras show that Captain Pennycuick has not appreciated the importance of keeping the work as much as possible at one level so that unequal

unequal settlements may be reduced to a minimum.

The sill of the watershed cutting will be 104 feet above deep bed of river and only 31 feet below full lake level. So the keeping of the water up to the level of the dam would at most enable water, and that in comparatively small quantities, to be diverted to the Madura District one season earlier than would otherwise be practicable. This advantage would be far more than counterbalanced by constant interruptions to the work, which, even supposing that no serious damage were to result, would very possibly postpone the diversion of water for more than one season. Para 30

Water transport would be an advantage resulting from the formation of a lake above, but it would be necessary several times in a season to re-arrange the jetties or other conveniences for the transfer of materials from carts to boats and vice versa. Indeed, seeing that such materials would generally have to be deposited at some distance from the dam itself, it is doubtful whether water transport with the necessity

necessity for breaking bulk twice and for constructing boats would effect any considerable saving.

Para 49. The principal material to be brought from a distance for a masonry dam is lime and of this 4,00,000 to 4,10,000 parahs or some 20,000 tons would be required. This is an outside estimate as the lime would not ~~not~~ be slaked before transport.

Supposing the whole of this material to be brought to the work in 4 seasons of 6 months each the average daily traffic would be nearly — 28 tons

Apparently about 1000 labourers of sorts would be employed and their food may be taken to weigh about 2 lbs per man. — say 1 "

Tools and stores would not average — 1 "

Total 30 Tons

In some further calculations Captain Pennycuick reduces the quantity of lime by one half - so the total load would upon that basis be only 16 Tons

[illegible] Tramway [illegible] contemplated but not by [illegible] Traction Engines —

The distance that lime would have to be brought is
~~It may safely be assumed that it could~~
15 miles and the cost of its transport by carts would be
~~not pay to construct and stock a tramway~~
5 to 5½ annas a parah (4000 cubic inches) - taking
~~to supersede 90 carts for a period of 6~~
Rupees 30 a month as the hire of a Cart. Captain
~~years working only half the year.~~
Pennycuick has not given the data for his rate of 2 annas

Para 50. The undersigned does not think it safe to estimate the cost of rubble masonry at

at the Perryaur at Rupees 7 a cubic yard. What is known is that every thing there will cost more than twice as much as it does in the plains, and work in the latter which could be accepted would cost more than 3½ Rupees. A great many matters have to be attended to. The stone used in particular layers all over the dam should approximately be of equal size — there must be no large spaces filled in with chips and mortar after the usual fashion — a fashion not perhaps very objectionable where weights and strains are on a small scale.

The front face wall would practically be an independent casing wall and would have to be built very carefully of coursed rubble. Concrete probably will cost more than Rs 4 a cubic yard. Para 51

Ashlar work such as would be necessary for a culvert would cost not less and possibly much more than 40 Rupees a cubic yard.

The estimates given in this para would need material modification if they are to be compared with the estimate for a silt dam prepared by Mr. R Smith and while Para 53

43 33

while it is by no means impossible that the rates allowed might in practice be approximated to under unusually good executive arrangements they will not do as an indication of what this part of the project will probably cost. but stone work is every where costly when granite is the material used, and for any work of this kind a very ample rate will be necessary.

A.M.C.S.
for Chief Engr. for Irrigⁿ

P. W. Works Form No. 3.

FORMER CASES.

Current No.	of 187
" 4	"
" 4	"
" 4	"
" 4	"

Current No. 279.

From

The Chief Engr. for Irrigation

No. 14
Dated 5th Jany. 1876
Recd. 14th " 1876

Subject:— Submitting with remarks Capt. Pennycuick's note on the diversion of the Pennar.

LATER CASES.

Current No.	of 187
"	"
"	"
"	"

ENCLOSURES. 6 2

From D.E. Nellore to Ch.E. for Irr.
" D.E. North Arcot notes of —
" D.E. Nellore "
" 3 Plans. "
" "

Orders and Proceedings in file.

Department.	No.	Date.	ENDORSEMENTS. Department.	No.	Dated.
P.W.D.	2466	18-7-69			
	1236	12.5.70			
	2680	9-11-70			
	1236	4.5.71			
	~~764~~	~~18.3.75~~	[illegible]		
	[illegible]	[illegible]			
	1193	30-4-75			
	2281	6-8-75			
	3762	26.11.69.			

No 560.

Recd — [illegible]
Re Cu - 13.6.76 Retd 27.6.76
Re Cu - 5/6/76 Retd 13.6.76
Cu - 24.8.76 - Retd 30/8/76
[illegible]

CHIEF ENGINEER
APR
1876
FOR IRRIGATION

GOVERNMENT OF INDIA.

PUBLIC WORKS DEPARTMENT.

CIVIL WORKS.
Irrigation.

To

THE SECY. TO THE GOVT. OF MADRAS,
IN THE P. W. DEPT., IRRIGN. BRANCH.

No. 159 I.

Dated March 28, 1876.

Received April 8th.

Communicates remarks and observations regarding the Perryaur Project.

No. 379, P. W. D. Press—29-3-76—34.

FORMER CASES.

I No. 1495-1-of 1876.

" "

Receipt No.

Dated

LATER CASES.

No. of 187 .

" "

REMINDERS RECEIVED.

No. 1, dated 187 .

" 2, " "

" 3, " "

" 4, " "

" 5, " No 560a "

Keep-Withs.

Red. f.—At 27-6-76
Delii. 13.6.76 Rtd 27.6.76
Delii-5/6/76 Rtd 13.6.76
Deli-24/5/76 Rtd 30/5/76
[illegible] Sheet 34 May

I FORM No. 29.

Register No. 13 G. I.

From

Government of India

I
No. 159.
Dated 28 March 1876.

Subject:— Perryaur Project.

To E.I.
~~Dr.~~ # Acct
8-4-76

ENCLOSURES.

From to

" "

" "

" "

Orders and Proceedings in file.

No.	Date.	No.	Date.
1194	30 April/75		
1193	Do		
2005	14 July/75		
2281	6 August/75		
8	2 Sept/75		
96	16 Oct/75		
162	22 Nov/75		
5	7 Feb/76	Letter to Secy of State for India	
205	26 Jany/76		

PUBLIC WORKS DEPARTMENT.

Endorsement of the Chief Engr. for Irrigation No. 14 dated 5th January 1876.

Letter from the Govt. of India No. 159 I. dated 28th. March 1876.

FOR ORDERS.

[illegible] Lt. Colonel R.E.
Joint Secretary to Govt.
P.W.D.

[illegible]

We must accept this offer I think – tho' I doubt whether we are likely to gain much in the direction we require from the Committee named.
It will be for the Chief Engineer to ~~determine~~ suggest the officer to be selected by our Govt to confer with the Committee

R.H.

[illegible] 27/5

But the information referred to in para. 5 must be first obtained

[illegible] 29/5

[illegible]

FOR ORDERS.

C 4792
49
25-74.

Circulate

Lum

No. 1619

Note:- the procgs. must go to G. of I. with the letter

Public Works Department. 38

PROCEEDINGS of the MADRAS GOVERNMENT.

29/6

UNDER date the 27 June/76.

READ the following:—

85

Endorsement by the Chief Engr. for Irrigation on Letter from the Supg. Engr. Nellore No. 58 d/ 19th Octr. 1875	H.E. No. 1229 d/ 20th Octr./75.
Note by Mr. R. Smith d/ 19th Octr. 1875 " " Captn. Pennycuick d/ 13th Octr. 1875 with endorsement and marginal remarks by the Chief Engr. for I.	(Hd. No. 14 d/ 5th Jany. 1876)
Letter from the Govt. of India	(Hd. No. 159 I of 28th March 1876)

All these papers must be printed.

See note at Board Bd

PML

See note on last ...

Ordered that the following letter be sent.

(H.E. No. 1620 d/ 27 June/76.

No. 1620.

To The Secy. to the Govt. of India

Sir,

I am directed in reply to

7/6

C.E. for I. with Enclo.

Copy to the Rev. Dept. (14-5)

Despd. from Ooty on the 2/7/76

to your letter No. 159 of the 28th March last to transmit for the information of the Government of India a copy of the Proceedings of this Government as per margin* containing the further information on the Engineering features of the Periyaur project, which has been obtained since orders were passed on the papers printed in Proceedings Madras Govt. of the 30th April 1875 No. 1193.

*No. 2281 d/6th Augt. 1875
" 205 " " 26th Jany. 1876.

2. I am at the same time to transmit a copy of the Proceedings of this Government in the Revenue Department in which the arrangements for ascertaining definitely what results may be

No. 1236 d/16th August 1875.
" 1436 " " 29th Septr. "
" 1594 " 6th Novr. "

expected

8739

expected from the diversion of water from the Perryaur to the plains of Madura will be found detailed.

3. With regard to the latter part of para 5 of your letter I am to say that Mr R. Smith the Officer, who was best acquainted with the site, No. 4, ultimately chosen for the dam, died in January last and it is difficult therefore to obtain at the moment more precise information as to the nature of the rock at this site. A description of the rock at sites Nos 2 & 3 is however given in para 6 of a Note by the Chief Engineer for Irrigation and it is believed that the character of

P.M.G. No. 3763 d/ 26th Nov. 1889
copy enclosed.

of the rock there does
not materially vary from
that at site No 4. From
various parts of Mr R. Smith's
reports it may be inferred
that the rock is everywhere
solid and compact e.g.
"It is generally admitted
"that the best foundation
"for a reservoir embankment
"is clay, and that the next
"in order is compact rock.
"If the Perryaur Lake em-
"bankment is constructed
"at No 2 or at No 3 site
"the foundation will be
"the same material i.e.
"sound rock". Again "The
"escape tunnel has been
"aligned and planned to
"suit the contour of the
"solid rock". Also in the
Memorandum on the head
works

para 9 of Memorandum dated 30th Octr 1871.
P.M.G 30th April 1875 No [illegible]

para 48 do

dated 15th April 1872 para 5

works proposed for No. 4 site.
"The reservoir embankment will
"be composed of silt throughout,
"and, to guard against leakage
"in the base or sides, trenches
"will be cut in the rock in the
"bed of the Perryaur and on
"both banks of this river"

para 26 "The tunnel to pass the Perryaur
"during the formation of the reservoir
"embankment will be cut in
"the rock on the left bank of
"this river".

para 32. Referring to the site for the
permanent escape it is
remarked that the average
level of the compact rock
is 120 feet above datum, and
there are many other passages
tending to show that there
is solid rock almost every
where at no great distance
below

below the surface, while in the bed of the river it is exposed. Though no where so recorded, the Chief Engineer for Irrigation who visited the Perryaur in 1869 is of opinion that the whole of the rock is of igneous formation, and that there is any quantity of stone suitable for either rubble or ashlar masonry. Lime is obtainable at Goodaloor "five miles from the foot of the Ghât and fifteen from the site of the dam"

4 ~~I am also directed to~~ state that His Grace the Governor in Council concurs in the views expressed by the Govt. of India as to the appointment of the Committee named

para 49 of Captain Pennycuick's Note dated 13th Octr. 1875.

P. M. G. No. 1619 d/27th June/76

Fair copy of [illegible] for the [illegible]

41

4. Having now supplied all further information available that can be given regarding this Project I am further directed to say that, with all deference to the judgement of the Government of India the suggested Committee does not appear to meet the object sought by the Government of Madras. The Governor in Council is of opinion that this scheme should not be considered by a Committee composed only of Indian Engineers. It is not by such a Committee that the object proposed in para 3 of the Proceedings of Government

No:

No: 1193 of 30th April
can be obtained - that
object was to obtain
the opinion of the highest
Engineering talent
available either in the
United Kingdom or
elsewhere as to the best
means of dealing with
the problem that has
to be solved - the con=
struction of the proposed
work, with other ma=
terials, such as stone
or Iron, in lieu of silted
earth. There is little
or no experience availa=
=ble in this country
as to design and con=
struction in such
materials; while it
is believed that there
are extensive works
of this nature elsewhere
from

93 42

from the Constructors and designers of which valuable advice and information might be obtained. If His Excellency the Viceroy in Council is unable to see his way at the present to making the reference suggested His Grace the Governor in Council will have to consider this im-portant and in-teresting question as for the present laid aside.

Revised para -

4. Having now supplied all further information ~~obtainable~~ available that can be given regarding this Project I am further directed to say that with all deference to the judgment of the Government of India, ~~His Grace the Governor in Council cannot rest satisfied with the proposal to refer the scheme for consideration of any~~ Committee composed only of Indian Engineers. It is not ~~there~~ that the object proposed in para 3 of the Proceedings of Government No 1193 of 30th April can be attained; that object ~~being~~ was to obtain the opinion of the highest Engineering talent avail-

[Margin note:] The suggested Committee does not appear to meet the object sought by the Govt. of Madras. The Govr. in C. is of opinion that this ~~project~~ scheme should not be considered by a

[Margin note:] by such a Committee

ble other in the United King-
dom or ~~abroad~~ elsewhere as to
the best ~~means~~ of
dealing with the prob-
lem that has to be solved,
the construction of the proposed works
with other materials,
such as Stone or Iron,
in lieu of silted Earth. There
is little or no experience availa-
ble in this Country
as to design and Con-
struction in such
materials; while it is believed that there are extensive works of this nature elsewhere from the ~~design~~ constructors designers of which valuable ~~inform~~ advice & information might be obtained — ~~and~~ If
His Excellency the
Viceroy in Council
is unable to see his
way at the present to making the
Reference suggested ~~as desired~~
His Grace the Gover-
nor in Council will ~~must~~
have ~~respectfully submit~~
to consider this
important & interesting question
as

as for the present, ~~if not altogether~~, laid aside.

Cmw

named in para 4 of your letter, and proposes to nominate Lieutenant Rawson R.E. the only Officer now in the Country who was employed on the investigation of the project as matured, to serve on the Committee, and afford to the other members the local information which will be required.

My. 3/6

[illegible]

Despd from Ooty
20/7/76

Has he not been transferred to another Presidency? and is he capable? I should have thought Pennycuick would have been a better representative

M

Has not Pennycuick gone home? M

I rather thought Rawson too young – of insufficient experience in large works of construction

BM [illegible]

S 3 [illegible]

11-2-18 A-II

6797 279 181 2574 A

Govt. of [1876] Madras

PUBLIC WORKS.

To

the Chief Engr. for Irrig.

Dated

Issued

Recd

G. O. 27th June 1876, No. 1615 / 1616

Nos. 559 @ 562

Sent in Reg 29-7-76

Periyaur Project

Madura D.

Papers containing further information in regard to the ——— ordered to be forwarded to the Govt of India

Transmitting in observations papers containing further information on the Engineering features of the Periyaur Project in the Madura Distt.